Lecture Note 1

Communication Theory (KEEE343_03)

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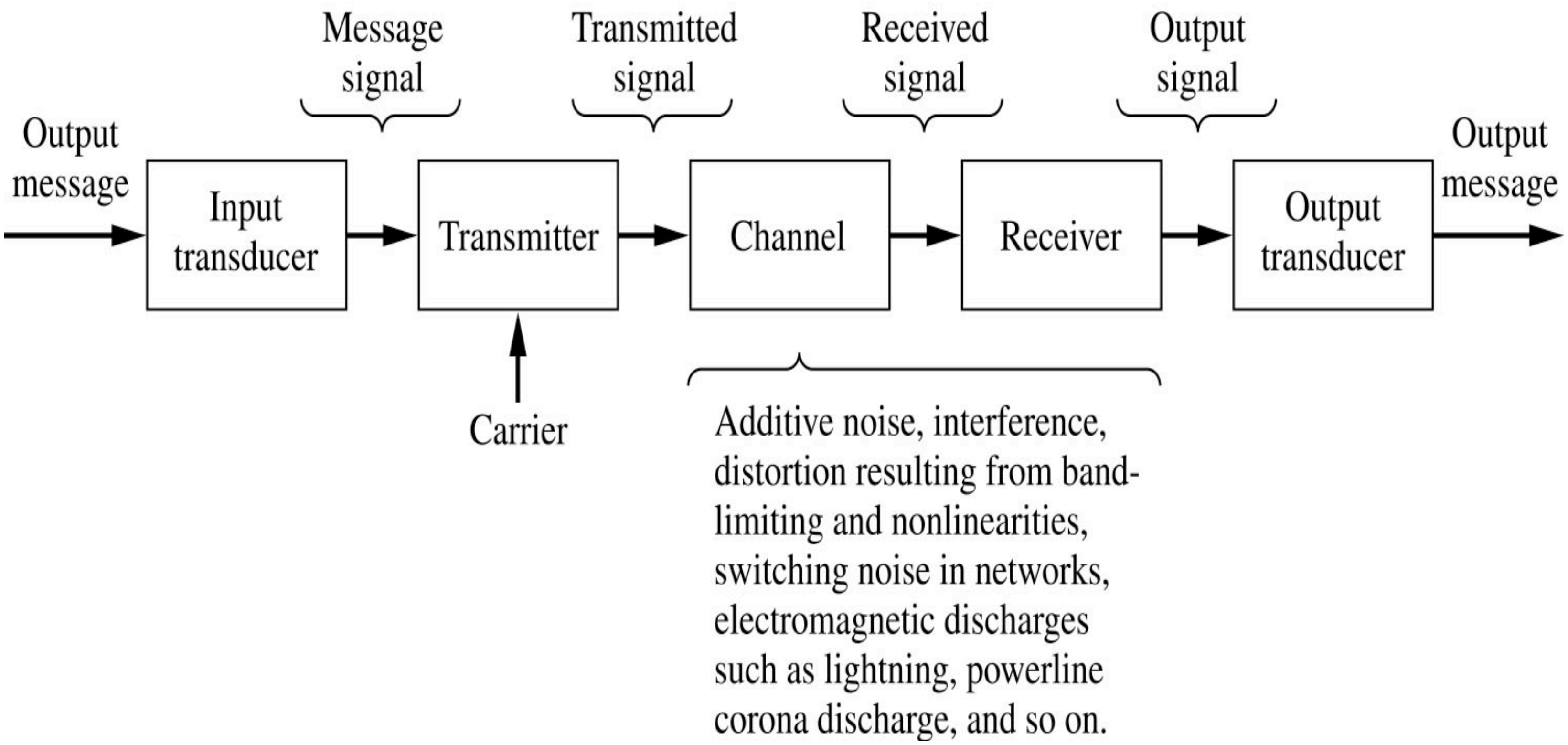
History of Communications

- 1887 J. C. Maxwell: Maxwell's theory
- 1897 G. Marconi: wireless telegraph system
- 1915 Bell System completes U.S. telephone line
- 1920 ~ 1936 AM/FM/PCM, TV broadcasting
- 1948 C. Shannon's "A Mathematical Theory of Communications"
- 1960s Satellite systems
- 1970s First commercial wireless personal communications
- Late 80s~early 90s 1st generation wireless communication systems (AMPS): Analog communications
- 90s~late 90s 2nd generation wireless communication systems (GSM, IS-95, EDGE, etc.): Digital communications
- Late 90s ~ current 3rd generation wireless communication systems: high speed digital data/voice communication
- 4G wireless communications systems are being defined.

- **More than 100 Years of history in the field of communications**

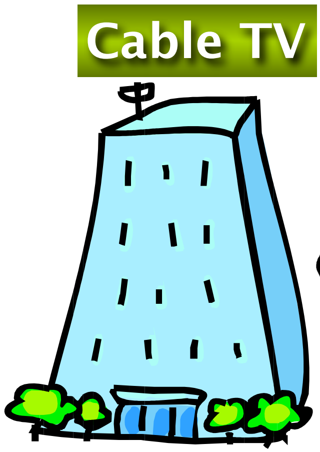
Block Diagram of a Communication System



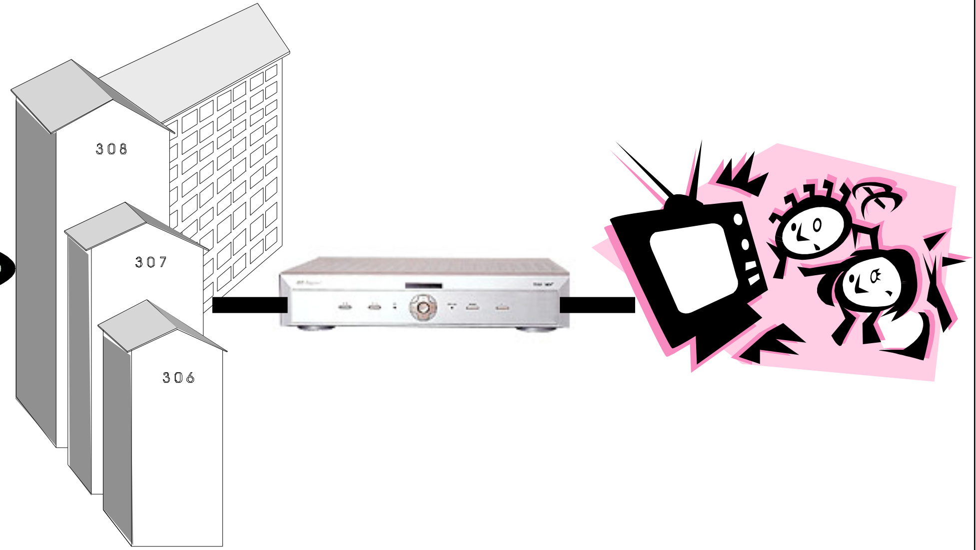
Message

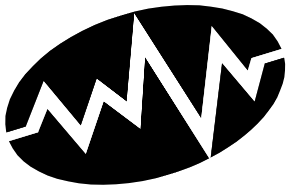
- Categorization of the Message
  - Analog
    - Pressure, Temperature, Speech, Music
  - Digital
    - Written text
- Signal
  - Convert the message into the signal
    - Message must be converted by a transducer to a form suitable for the particular type of communications.
  - Electrical Communication
    - Message -> Transducer (Microphone) -> Signal (Voltage)

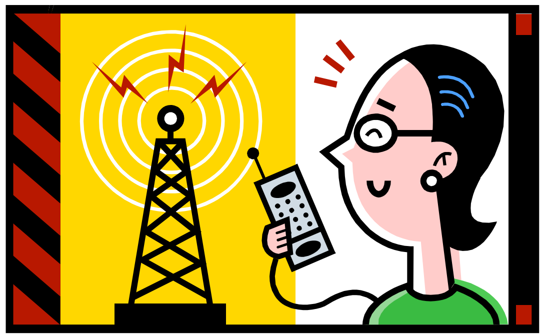
Channels



Wired channel
(coaxial cable)



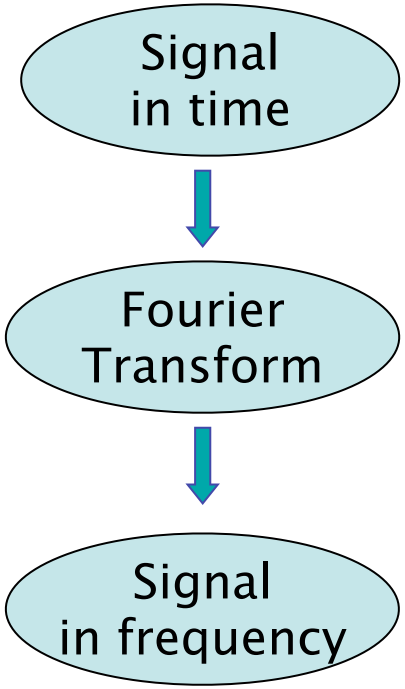




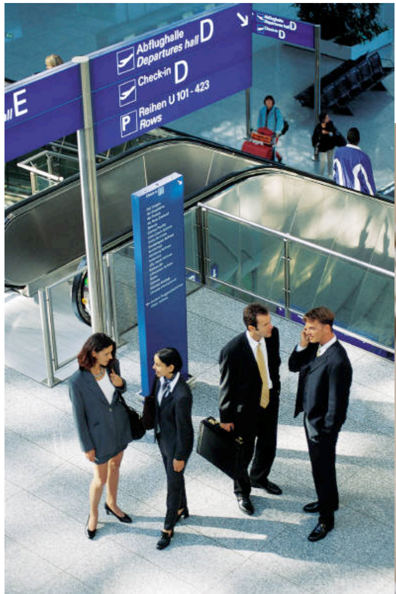
Wireless channel
(Air Interface)

Signals

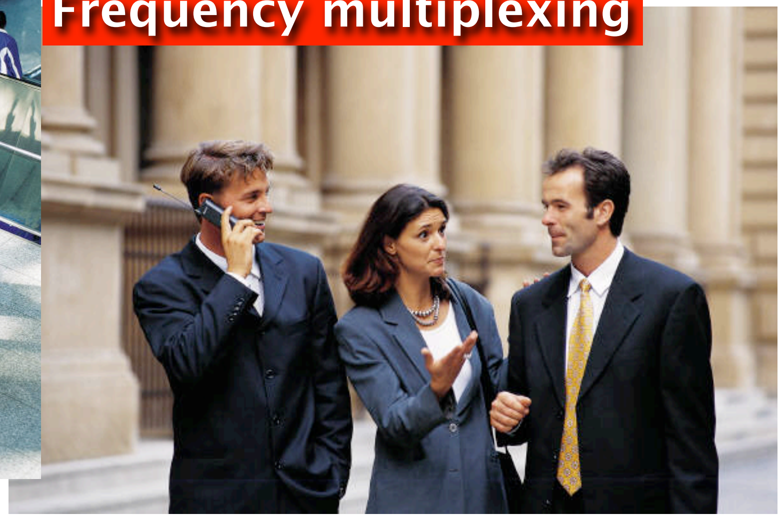
- Function of time
- Function of frequency



Only Time multiplexing

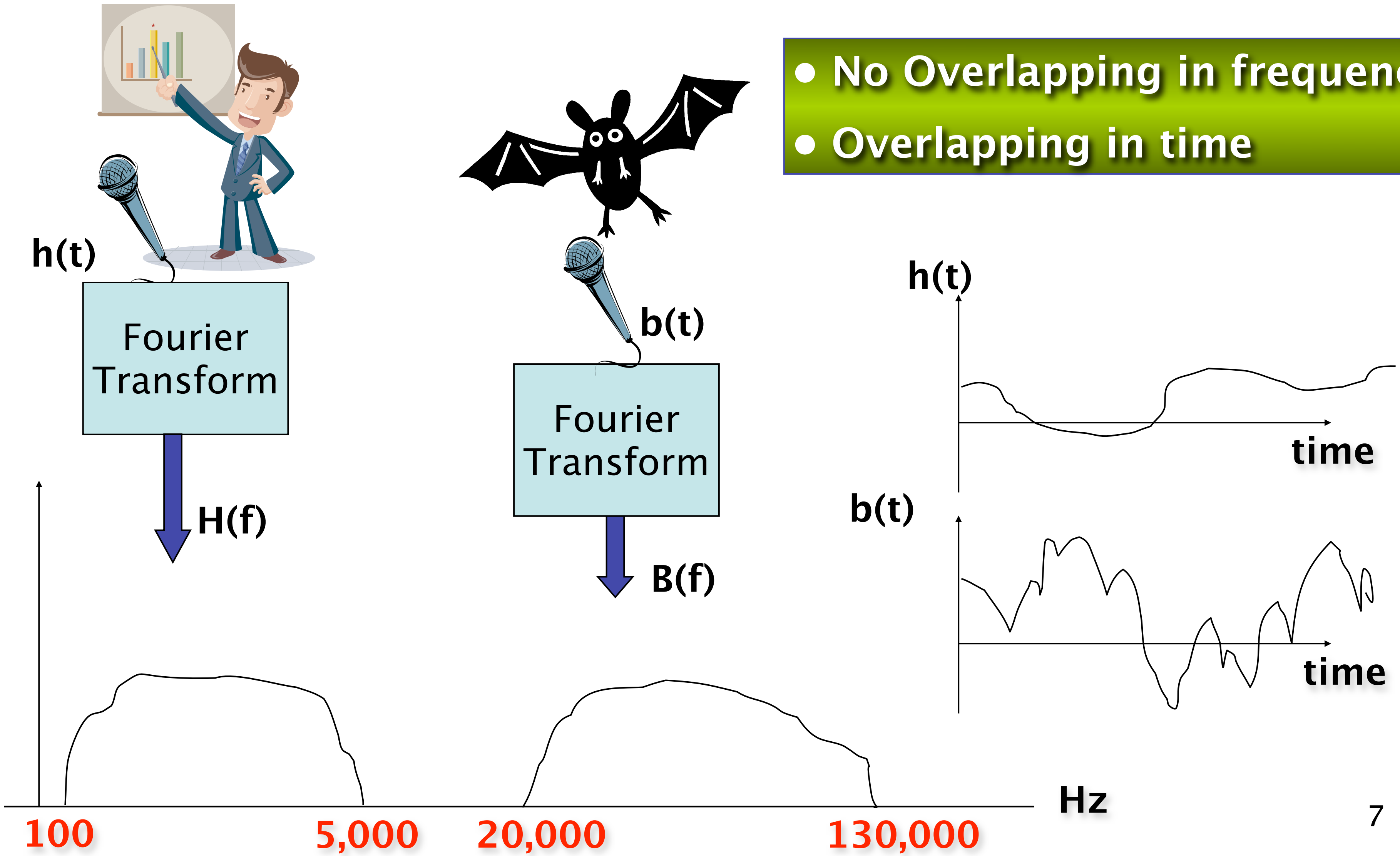


Time multiplexing
Frequency multiplexing

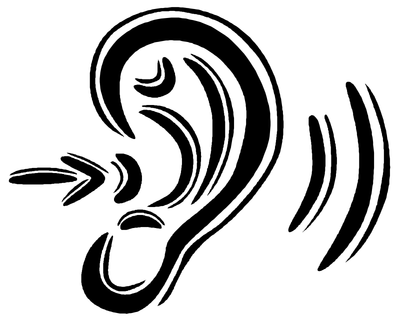


Time and Frequency

- No Overlapping in frequency
- Overlapping in time



Human Ear



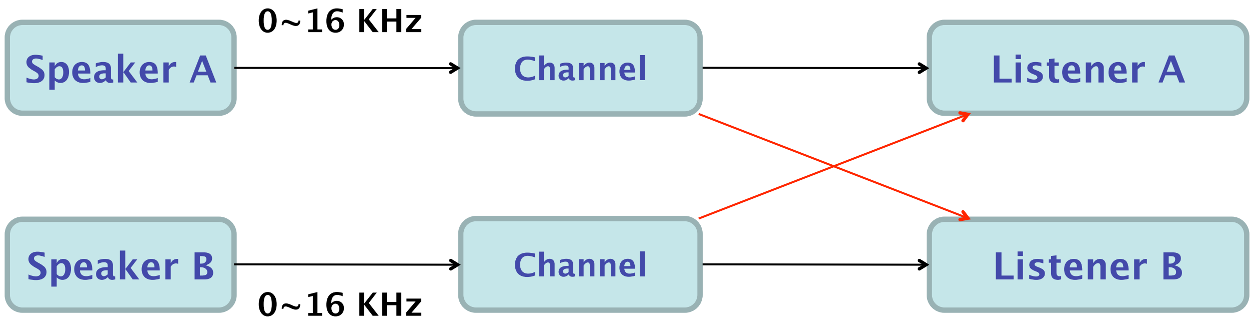
Audible Frequency Range: 0 ~ 16 KHz

Frequency

Use		Frequency
Human voice		**0.1 ~ 3.5 KHz**
Bat voice		**20 ~ 130 KHz**
AM		**540 ~ 1600 KHz**
Television	Channels 2–4	**54 ~ 72 MHz**
	Channels 5–6	**76 ~ 88 MHz**
FM		**88 ~ 108 MHz**
Television	Channels 7–13	**174 ~ 216 MHz**
	Channels 14–83	**420 ~ 890 MHz**
Cellular mobile radio	Mobile to base Base to mobile	**806 ~ 821 MHz** **851 ~ 866 MHz**

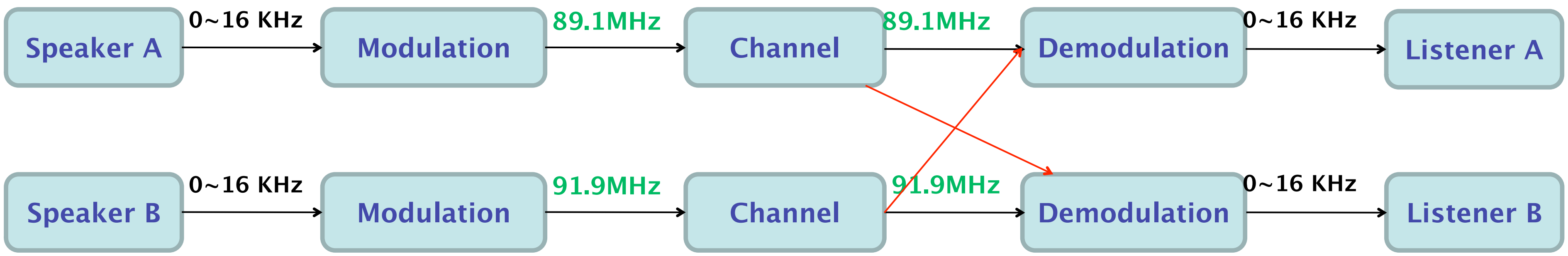
ISM band	Older microwave ovens; medical	**902~928 MHz**
Cellular mobile band	Base to mobile	**935 ~ 940 MHz**
Personal communication	CDMA cellular	**1.8 ~ 2.0 GHz**

Interference



Listeners cannot understand speaker A and Speaker B due to the interference.

Modulation and

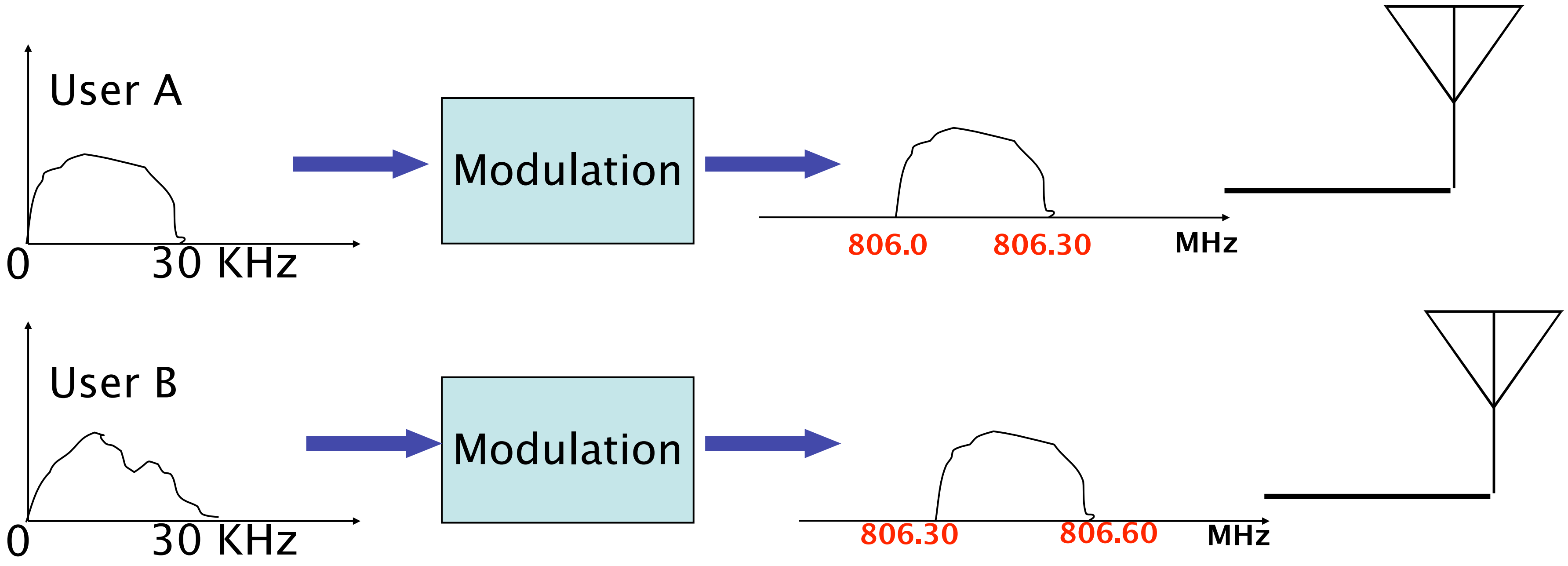


- **Modulation**
  - **Translate the baseband signal up to the passband signal.**
- **Demodulation**
  - **Translate the passband signal down to the baseband signal.**

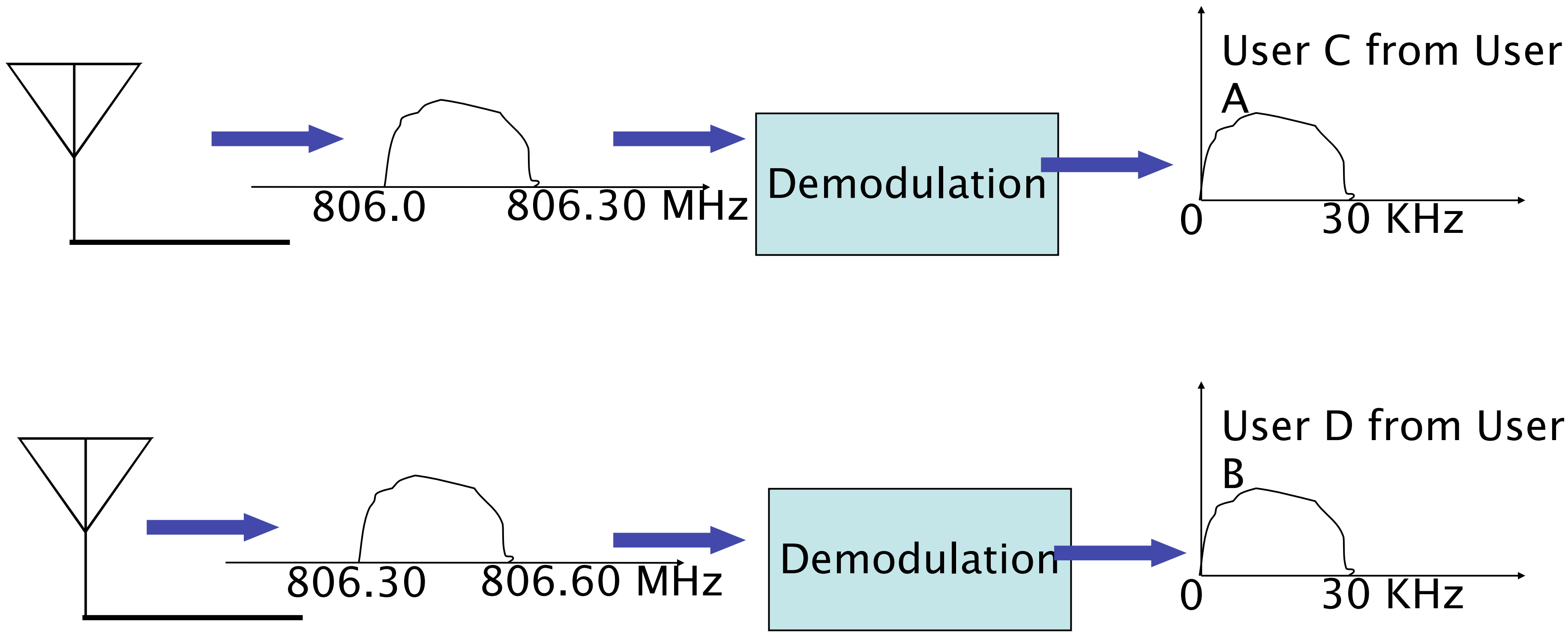
- **Question: How do we translate the band of the signal up or down?**
  => Use the Fourier Transform!!!

Personal Communication Example

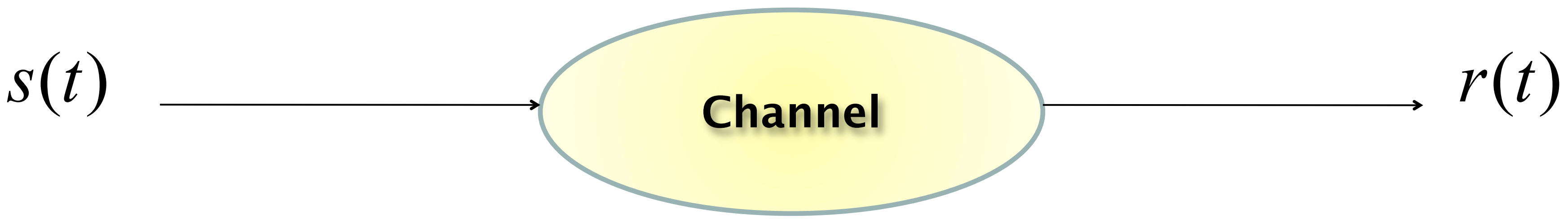
Cellular mobile radio	Mobile to base	**806 ~ 821 MHz**
	Base to mobile	**851 ~ 866 MHz**
	Mobile to base	**896 ~ 901 MHz**
	Base to mobile	**935 ~ 940 MHz**



Demodulation



Simple Model



- **Problem**
  - **r(t) might be different from s(t) due to weak power, interference, noise, etc.**
- **Objective**
  - **Solve the problem using the signal processing to make s(t)=r(t).**

Course Description

- Time and Frequency analysis
  - Signal representation
  - Fourier analysis
  - Fourier transform
  - Linear time invariant systems
- Modulation and Demodulation
  - Amplitude modulation (AM)
  - Angle modulation
    - Phase modulation (PM)
    - Frequency modulation (FM)
- Pulse Modulation
  - Transition from analog to digital
  - Delta modulation

Time and Frequency Analysis

- Signal Models
- Fourier Series
- Fourier Transform

Signal Models

- Deterministic and Random Signals
- Periodic and Aperiodic signals
- Phasor Signals and Spectra
- Singularity Functions
- Signal Classification

Deterministic/Random Signals

- Deterministic signals – completely specified as a function of time
  - Example
    - Sinusoidal function

$$x(t) = A\cos(\omega_0 t), \qquad -\infty<t<\infty$$

      - Where A and ω_0 are constants

    - Rectangular pulse

$$\Pi(t) = \begin{cases} 1, & |t| \leq 1/2 \\ 0, & \text{otherwise} \end{cases}$$

Periodic Signals

- Periodic signals if and only if

$$x(t+T_0)=x(t), \qquad -\infty<t<\infty$$

  - Where the constant T_0 is the period.
  - Fundamental period (or simply period) ~ smallest number T_0 satisfying the periodic condition

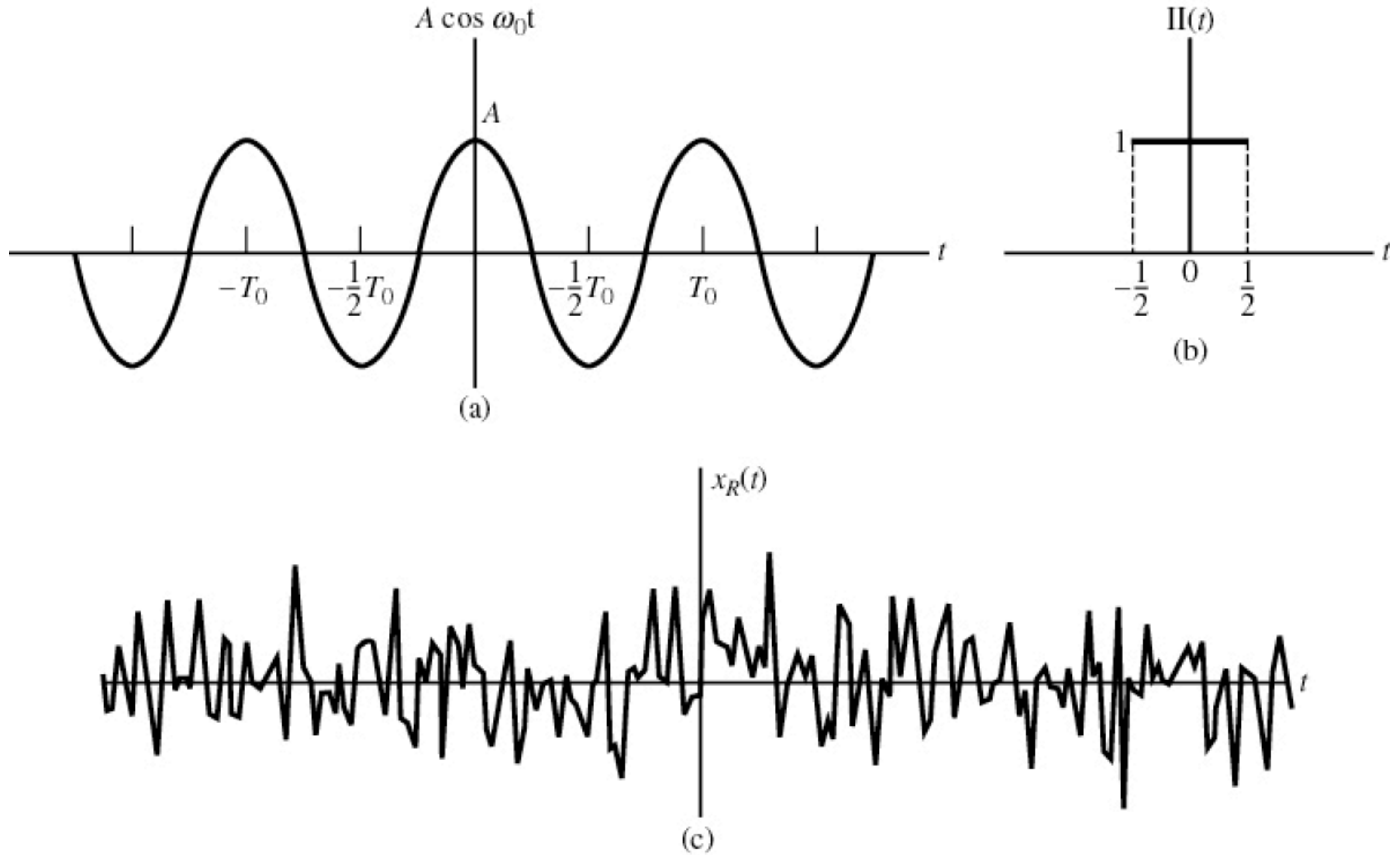


Figure 1. Examples of various types of signals.
(a) Deterministic (sinusoidal) signal.
(b) Unit rectangular pulse signal.
(c) Random signal.

[Ref: Haykin & Moher, Textbook]

Phasor Signals and Spectra

- Consider

$$\tilde{x}(t) = Ae^{j(\omega_0 t + \theta)}, \qquad -\infty < t < \infty$$

  - A : Amplitude
  - θ : Phase
  - $f_0 = 2\pi / \omega_0$: Hertz frequency

- $\tilde{x}(t)$ is rotating phasor from $Ae^{j\omega_0 t}$ to $\tilde{x}(t) = Ae^{j(\omega_0 t + \theta)}$

- Is $\tilde{x}(t)$ periodic?
  - To show this, you need to prove

$$\tilde{x}(t) = \tilde{x}(t + T_0)$$

  - Where $T_0 = 2\pi / \omega_0$

- Relation of rotating phasor with a real sinusoidal signal

$$x(t) = A\cos(\omega_0 t + \theta) = \mathrm{Re}[\tilde{x}(t)]$$
$$= \mathrm{Re}[Ae^{j(\omega_0 t + \theta)}]$$

$$A\cos(\omega_0 t + \theta) = \frac{1}{2}\tilde{x}(t) + \frac{1}{2}\tilde{x}^*(t)$$
$$= \frac{1}{2}Ae^{j(\omega_0 t + \theta)} + \frac{1}{2}Ae^{-j(\omega_0 t + \theta)}$$

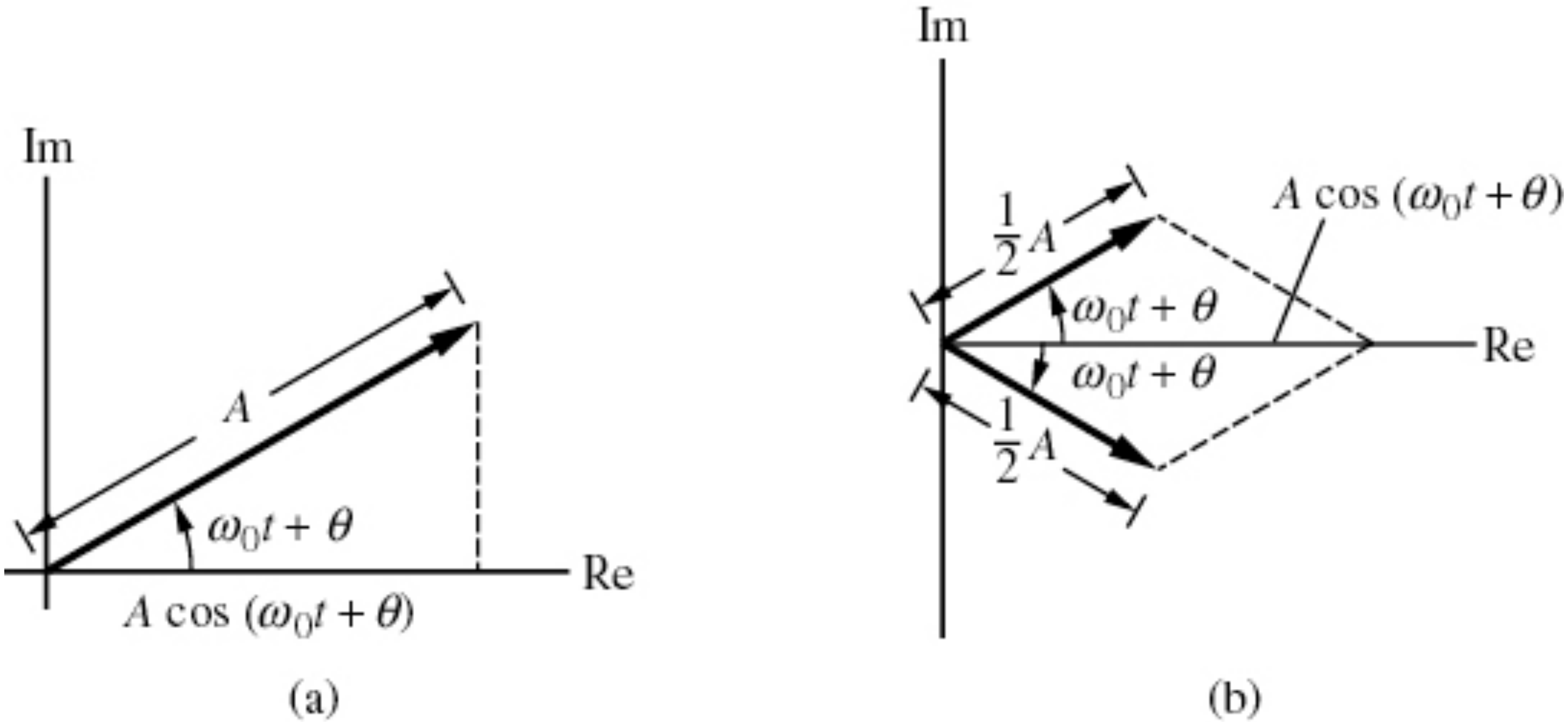


Figure 2. Two ways of relating a phasor signal to a sinusoidal signal.
(a) Projection of a rotating phasor onto the real axis.
(b) Addition of complex conjugate rotating phasors.